

# Command and Control for Simulated Air Agents

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# Outline

- \* Command forces for rotary-wing attack missions
  - \* Development of RWA Company Commander
  - \* Focus primarily on mission planning
- \* C3 for Fixed-wing air-to ground missions
  - \* Development of C3 nodes:
    - Ground Controller (GCI, TACC, TAD)
    - Forward Air Controller (FAC)
    - Airborne Early Warning (AWACS, E2C)
  - \* Focus on run-time assessments and resource allocation
- \* All entities implemented in Soar architecture

# Overview of Soar

- \* High-level: Rule-based system
- \* Provides basic architectural support for (and integration of):
  - \* Knowledge representation - rules and (simple) objects
  - \* Decision making - integration of preferences from rules
  - \* External interaction - I/Q through object passing
  - \* Reactivity - I/Q is within inner loop of decision making
  - \* learning - chunking of new rules from experience
  - \* Psychological modeling - time scales

# SOAR Applications

- \* General approach to planning and simulation
  - \* Rotary-wing Commander simulation (in DIS)
  - \* Navy Fixed-wing Pilot simulation (in DIS)
  - \* Navy C3
  - \* Firefighter virtual training environment
  - \* Natural Language understanding/protection
  - \* Cognitive Modeling
- \* Supported by large research community

# Resources

- \* ModSAF

- For entity simulation and low-level behavior

- \* SOAR

- For entity high-level behavior

- Each entity controlled by knowledge-base of 2000 rules

- Capable of planful and reactive behavior

- \* CFOR (Mitre)

- \* CCSIL - for inter-agent communication

- \* EU- for terrain reasoning

- \* Platform Services - for Commander's vehicle sensing

# PART I: CFOR - Goals

- \* RWA Company command entity in ModSAF

SCOPE:

- \* Attack mission
- \* Security mission
- \* Reconnaissance mission

- \* Battalion command entity

- \* Scope not yet determined

- \* Still in early stages of development

# CFOR Capabilities

- \* Inter-agent communication

  - Receive operation orders and situation reports

  - synchronize with other units (e.g. fire support, A C )

- \* Real-time assessment of battlefield

  - on-board sensors

  - remote sensors

  - inference of enemy intent

- \* Planning and Re-planning based on current situation

- \* Terrain Reasoning

# Typical Scenario

- \* Entities: Live Battalion Commander

  - SOAR/CFOR Company Commander

  - 5 SOAR/IFOR RWA"s

  - ModSAF OPFORs

- \* Battalion order given to SOAR/CFOR:

  - Advance along Axis OSHKOSH

  - Attrit Tank Battalion in engagement area BRAVO

  - Obey A<sup>2</sup>C<sup>2</sup>

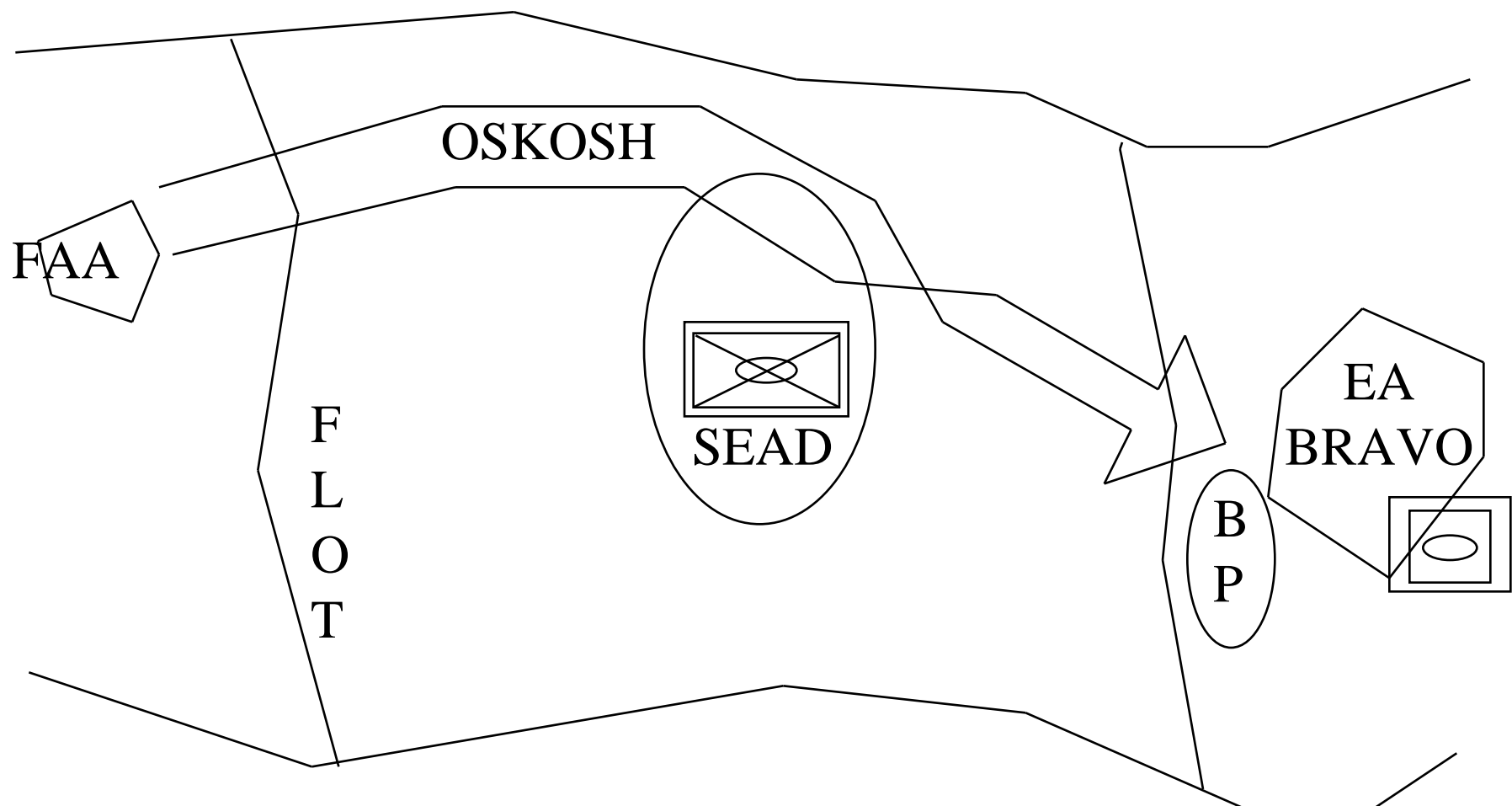
- \* SOAR/CFOR elaborates mission

  - Identify target priorities, firing positions...

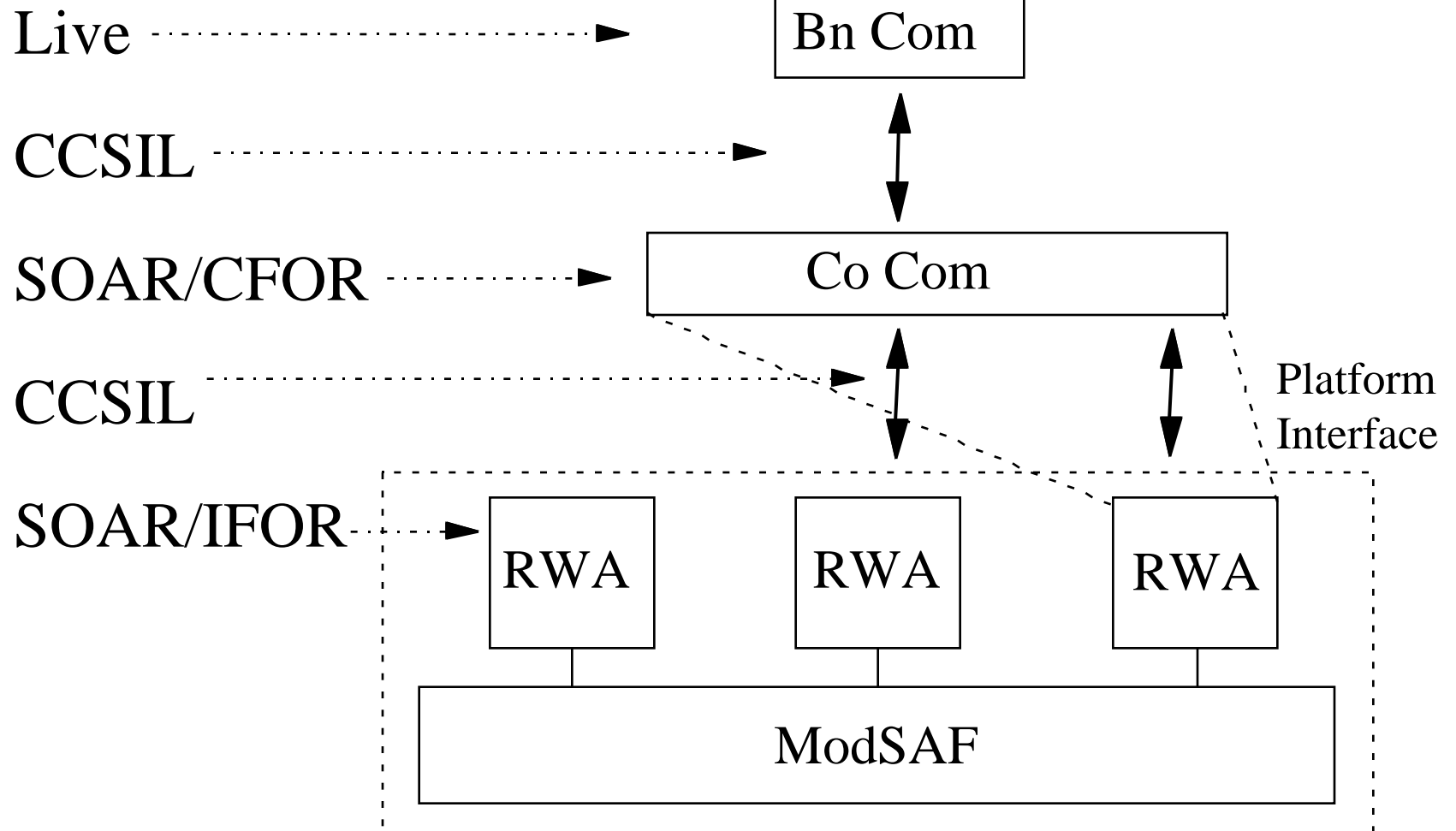
- \* SOAR/CFOR monitors execution and replans as necessary



# Typical Plan



# Architecture



# Knowledge Representation

- \* Mission planning and monitoring guided by explicit mission representation shared at all levels
- \* Roughly equivalent to CCSIL operations order
  - \* **SITUATION:** description of enemy forces, their location, and intents, plans of superior units
  - \* **MISSION:** sequence of tasks
  - \* **EXECUTION:** subordinate plans, coord. information
  - \* **COMMAND AND SIGNAL**
  - \* **Etc.**
- \* New information (e.g. Sit Reports) modifies this structure to facilitate dynamic decision making

# Mission Planning

## \* GIVEN

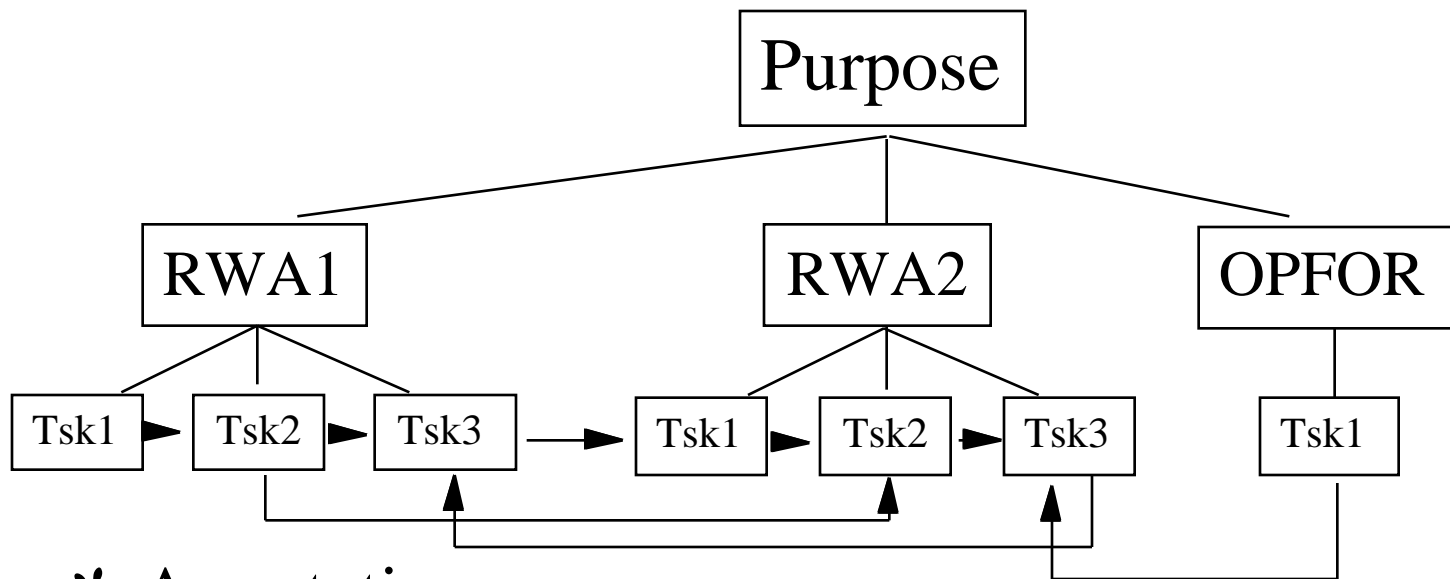
- \* CCSIL Bn Order - specifying abstract mission spec.
- \* Refinement “templates” for elaborating spec. (rules)
- \* “Standard Operating Procedures” for missing fields (rules)

## \* Generate CCSIL Co Order

## \* Annotate mission representation with dependency information

- \* Preconditions and effects associated with tasks
- \* Refinement assumptions added
- \* Timing constraints computed and attached

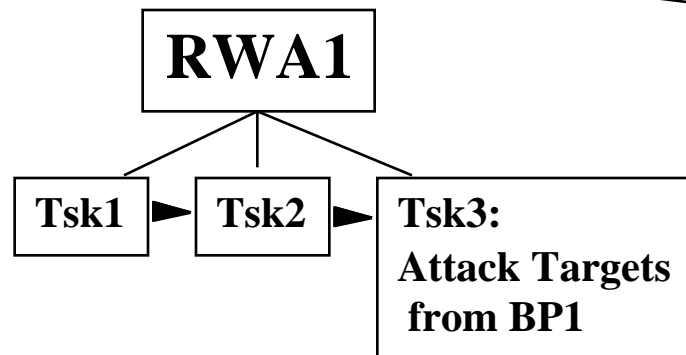
# Mission



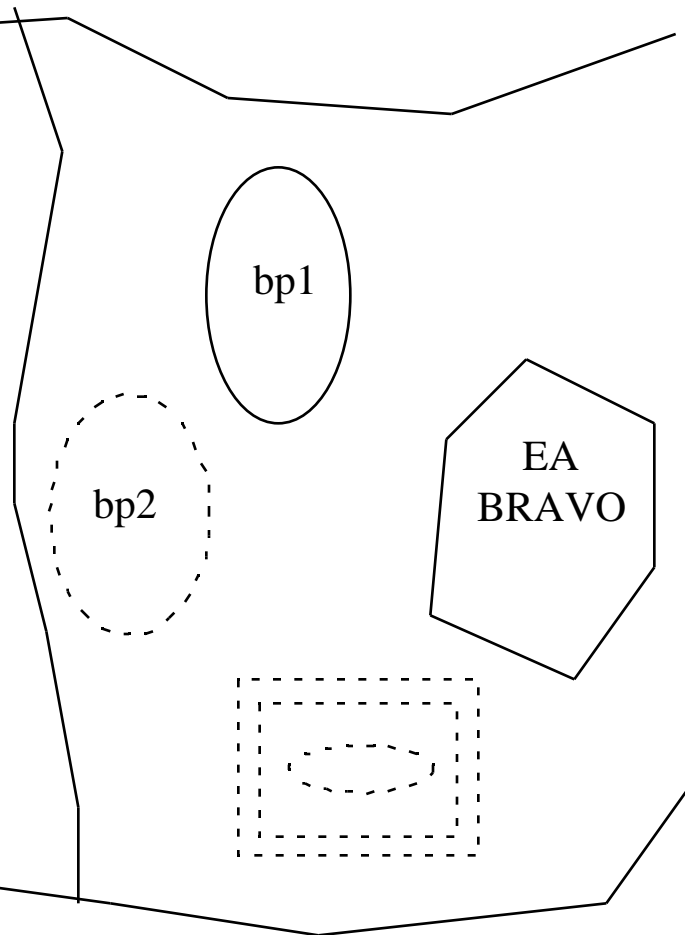
## \* Annotations:

- \* help recognize plan inconsistencies
- \* help propagate the effects of new information
- \* e.g. tasks are eliminated if their preconditions/assumptions become violated

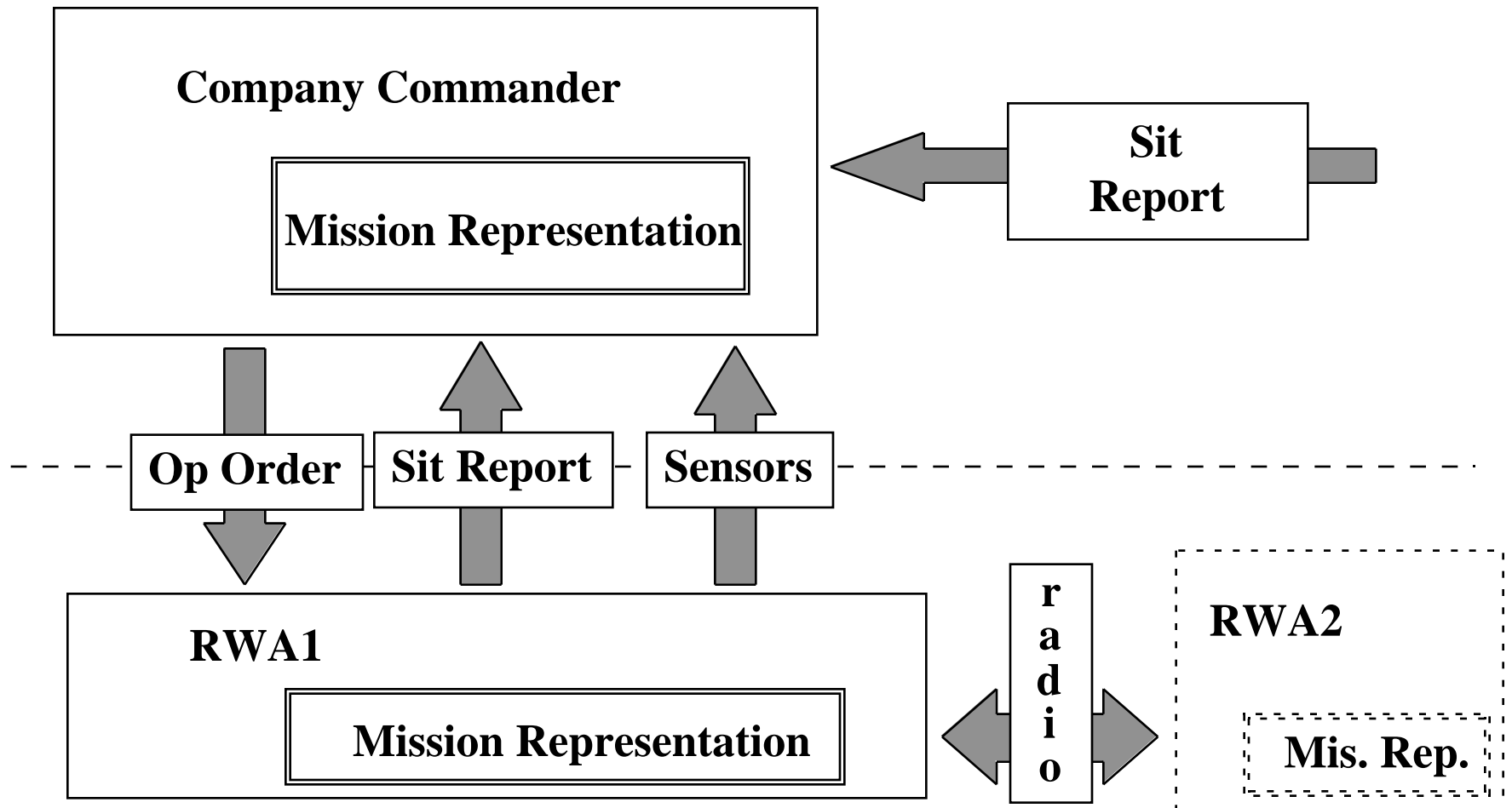
# Example



- \* Reach BP1 and enemy is not EA
- \* violates assumptions of Tsk3
- \* Initiates replanning
  - \* send out scouts
  - \* compute new BP



# Layered Approach



# Simulated Battle Context

## \* Level of decision Representation

- \* Company commander in charge of 2-8 RWAs
- \* goal of Battalion commander in charge of 2-3 co
- \* No long term predictions or resource management

## \* Representation of Current Battle State

- \* Maintained in mission structure
  - Determined by OpOrder, platform sensors, sit. reports
- \* Parameters; type/location of friendly/enemy units



# Simulated Battle context

## \* Representation of Friendly Battle Plan

- \* Entities represent Operations Order received via CCSIL
- \* Represented as data structures in rule-based system

## \* Representation of Enemy Objectives

- \* As given in operations order
- \* Limited abilities to infer if enemy is a threat
- \* New enemy can be identified through sensors

# Decision Process

## \* Assessment of Current/Future Status

- \* Commander objectives represented explicitly in op order
- \* Rules attempt to correlate sensors with objectives
- \* Projection limited to time/place incompatibilities

## \* Decision Actions

- \* Actions are transmitted via CCSIL
- \* Represented in explicit mission structure

# Decision Process

## \* Dynamic/Reactive Decision Making

- \* Entities react immediately to sensor inputs
- \* Command entity responds to changes in mission structure
- \* Replans as necessary to maintain integrity of plan

## \* Doctrinal Context

- \* doctrine is represented implicitly
  - Agents only represent doctrinally correct responses
- \* Architecture supports explicit representation
  - Could be expressed as rules that discard non-doctrinal actions

# Simulated Support

- \* Sensor support

- \* Sensors provide location, numbers, types, bearings
  - \* Intent must be inferred from sensors

- \* Information operation activities

- \* Friendly activities monitored via sensors and CCSIL
- New information has impact if it violates underlying plan

# Architectural Aspects

- \* Command levels at which Live Staff can be used

- \* Company Commander or above
- \* Required at Battalion command and above
- \* Extending simulation vertically

- \* Required Levels of Fidelity

- \* all entities simulated at individual unit level  
commander could be applied to aggregate entities  
requires CCSIL

# Other Issues

## \* Primary Issues

- \* Representing plan assumptions and dependencies
- \* Recognizing when dependencies are violated
- \* Representing and selecting multiple courses of action

## \* Research areas

- \* Modeling enemy intent
- \* “war gaming” plans to recognize bottlenecks, brittleness
- \* Learning/explaining plan failures

## Part II: C3 - Goals

### \* FWA Development of C3 nodes

#### SCOPE:

- \* Individual aircraft (F14, F18)
  - \* Section/Division/Package air lead
  - \* Ground controller (GCI, TACC, TAD)
  - \* Forward Air Controller (FAC & FAC(A))
  - \* Airborne Early Warning (AWACS, E2C)
- ### \* In support of Air-to-ground missions

# C3 Capabilities

- \* Inter-agent communication  
communications via simulated radio  
direct units and receive responses
- \* Real-time assessment of battlefield  
on-board sensors (visual, radar, radio)  
inference of enemy intent
- \* Direct subordinate units according to some pre-stated mission specification
- \* Each platform implemented in ModSAF of low-level  
High-level controlled by Soar/IFOR



# Simulated Battle Context

## \* Level of Decision Representation

- \* Individual, Section, Division, Package
- \* Air controller
- \* No long term predictions or resource management

## \* Representation of Current Battle State

- \* Depends on entity
  - Some use only radio reports (TACC and TADD)
- \* Most combine radio, radar, visual
- \* Parameters: type, position, heading, speed, altitude

# Simulated Battle Context

## \* Representation of Friendly Battle Plan

- \* Complete representation of own mission - little about others
- \* Represented as data structures in rule-base system

## \* Representation of Enemy Objectives

- \* Limited to whether enemy is threat or not
- \* Some threats known, others identified through sensing or radio

# Decision Process

- \* Assessment of Current/Future Status

- \* Rules attempt to correlate sensors with objectives
  - \* No attempt to project future status

- \* Decision Actions

- \* Decisions performed by acting radio messages

# Decision Process

## \* Dynamic/Reactive Decision Making

- \* Entities react immediately to sensor inputs
- \* Few actions preplanned - most in response to current sit.
- \* Much of plan representation is implicit in rule structure

## \* Doctrinal Context

- \* Doctrine is represented implicitly
- \* Agents only represent doctrinally correct responses
- \* Architecture supports explicit representation
- \* Could be expressed as rules that discard non-doctrinal actions

# Simulated Support

- \* Sensor support

- \* Sensors provide location, numbers, types, bearings
  - \* Intent must be inferred from sensors

- \* Information operation activities

- \* Friendly activities monitored via sensors and radio

Decision are responsive to those changes (e.g. lead killed)

# Architectural Aspects

- \* Command levels at which Live Staff can be used

- \* Humans can be used for any of the command levels
- \* All control must happen through simulated radio

- \* Required Levels of Fidelity

- \* all entities simulated at individual unit level

# Other Issues

## \* Primary Issues

- \* Capturing appropriate doctrine
- \* Handling real human communication

## \* Research areas

- \* Natural Language processing and speech understanding
- \* Spatial reasoning for battle planning